VLBI TRACKING OF THE PHOBOS SOIL MISSION

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on behalf of the PRIDE team

Joint Institute for VLBI in Europe

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Motivation

1. Can we use small and fast radio telescopes for spacecraft tracking?

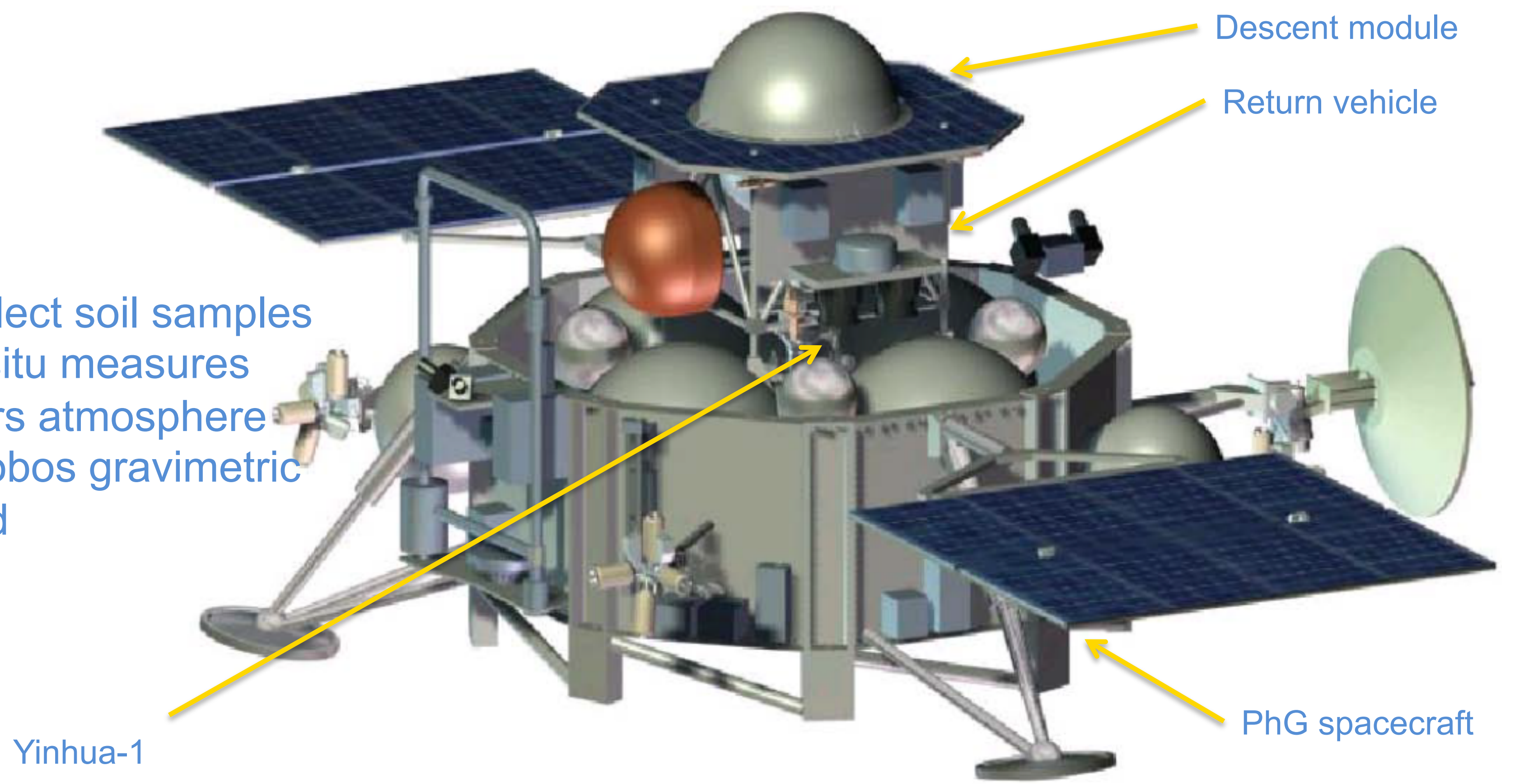
2. Can we use standard radio astronomy telescopes?

3. Can we get GPS accuracy on outer spacecraft within the Solar System?

4. Can we obtain the state-vectors estimates in real-time?

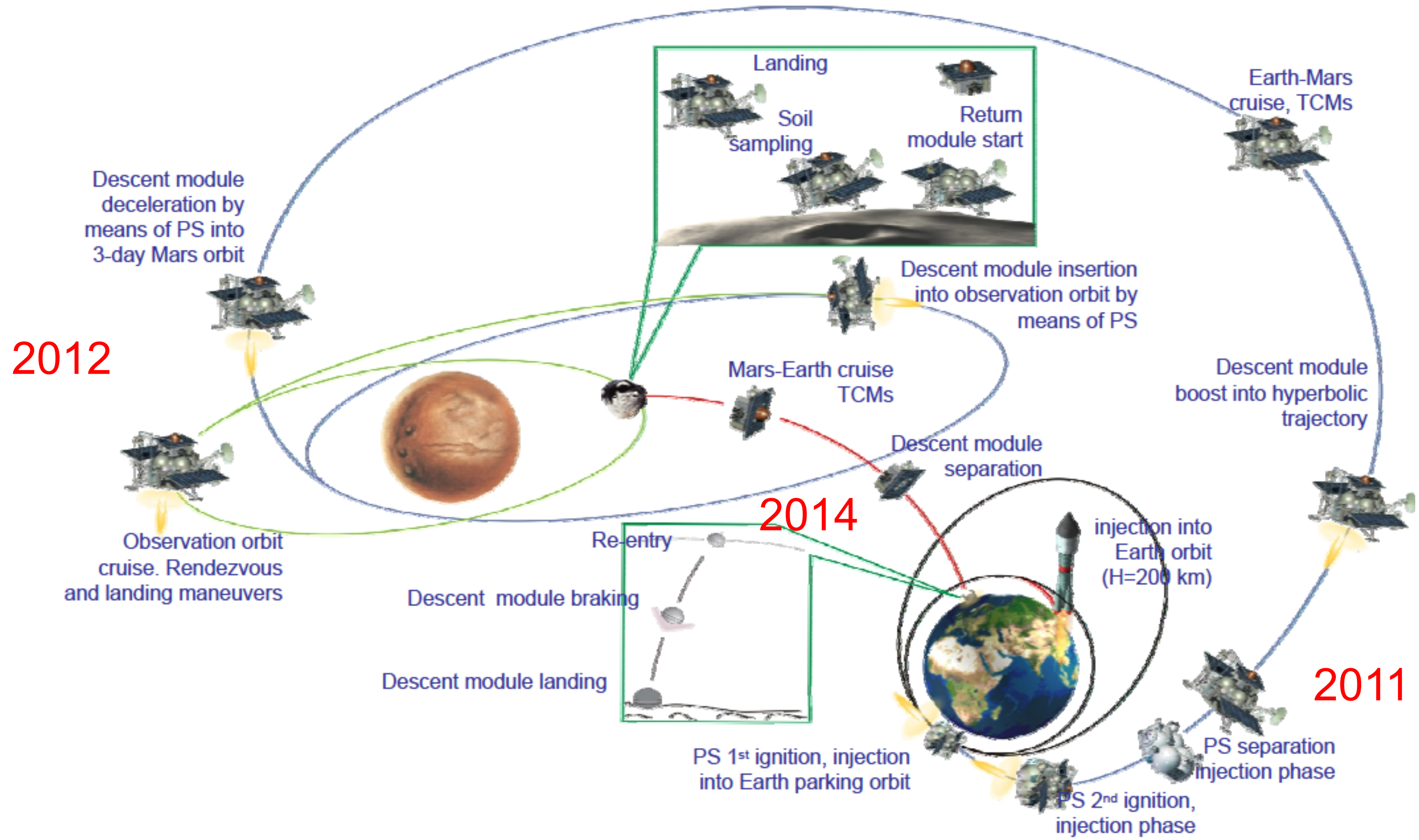
Phobos Soil mission

1. Collect soil samples
2. In-situ measures
3. Mars atmosphere
4. Phobos gravimetric field



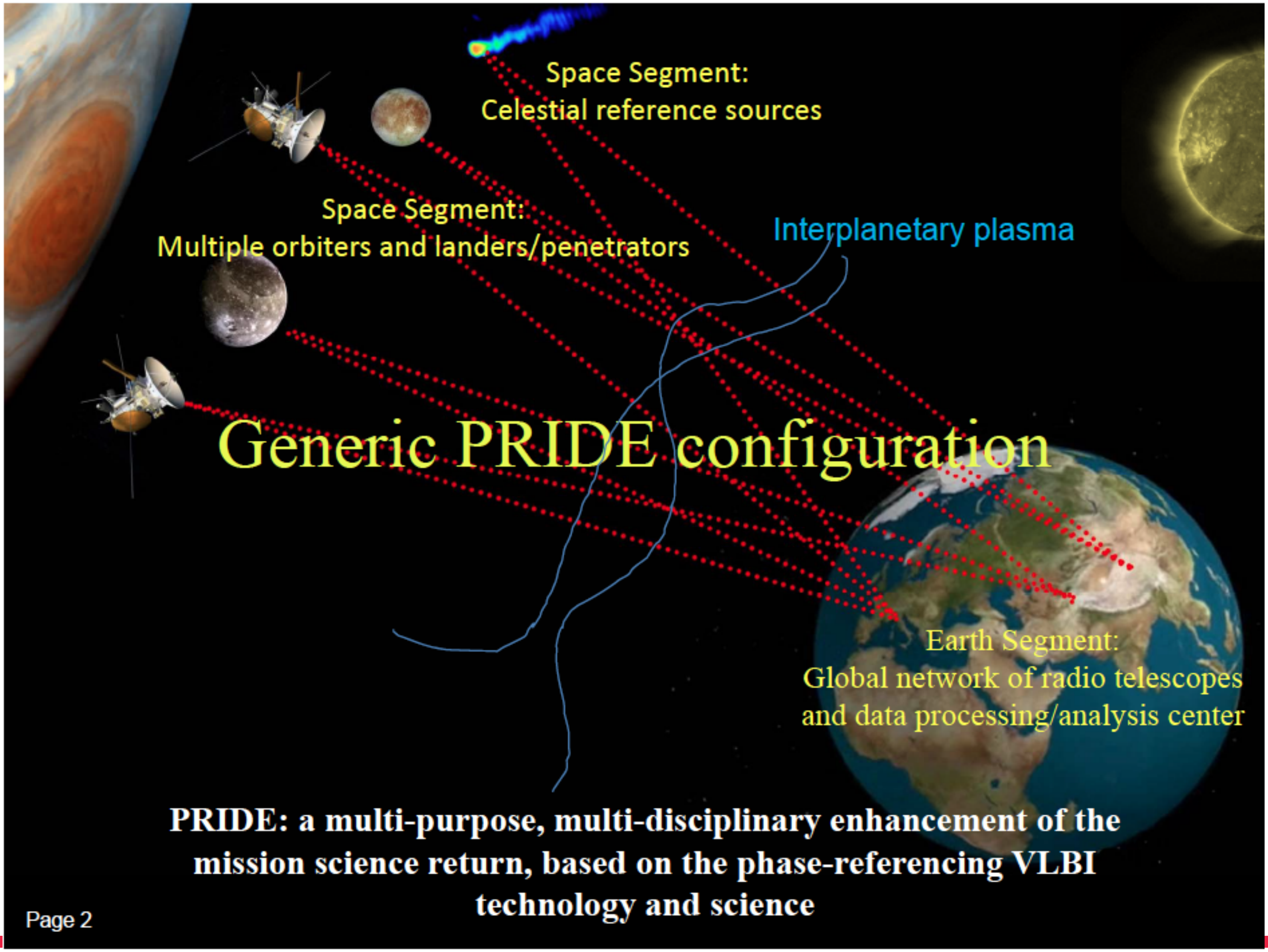
Phobos-Soil mission profile

PRIDE-Phobos will be crucial for study of celestial mechanics, gravimetric properties and during the EDL phase.



Courtesy by Zhakarov et al.

PRIDE configuration

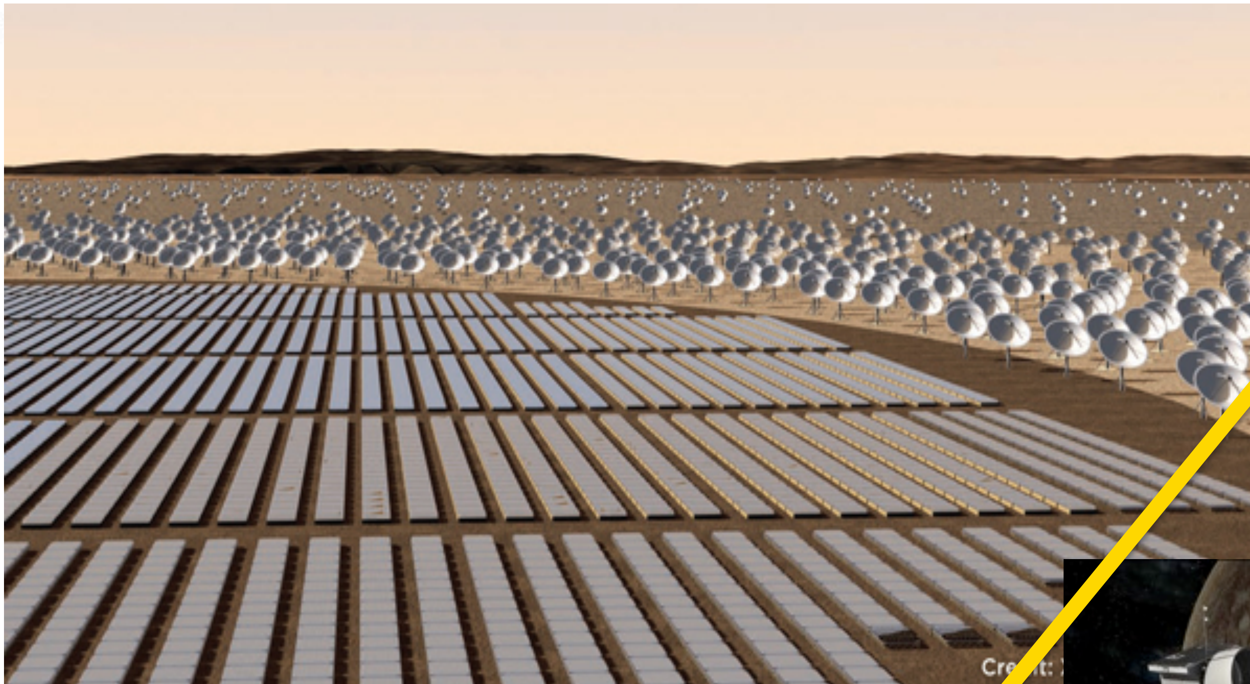


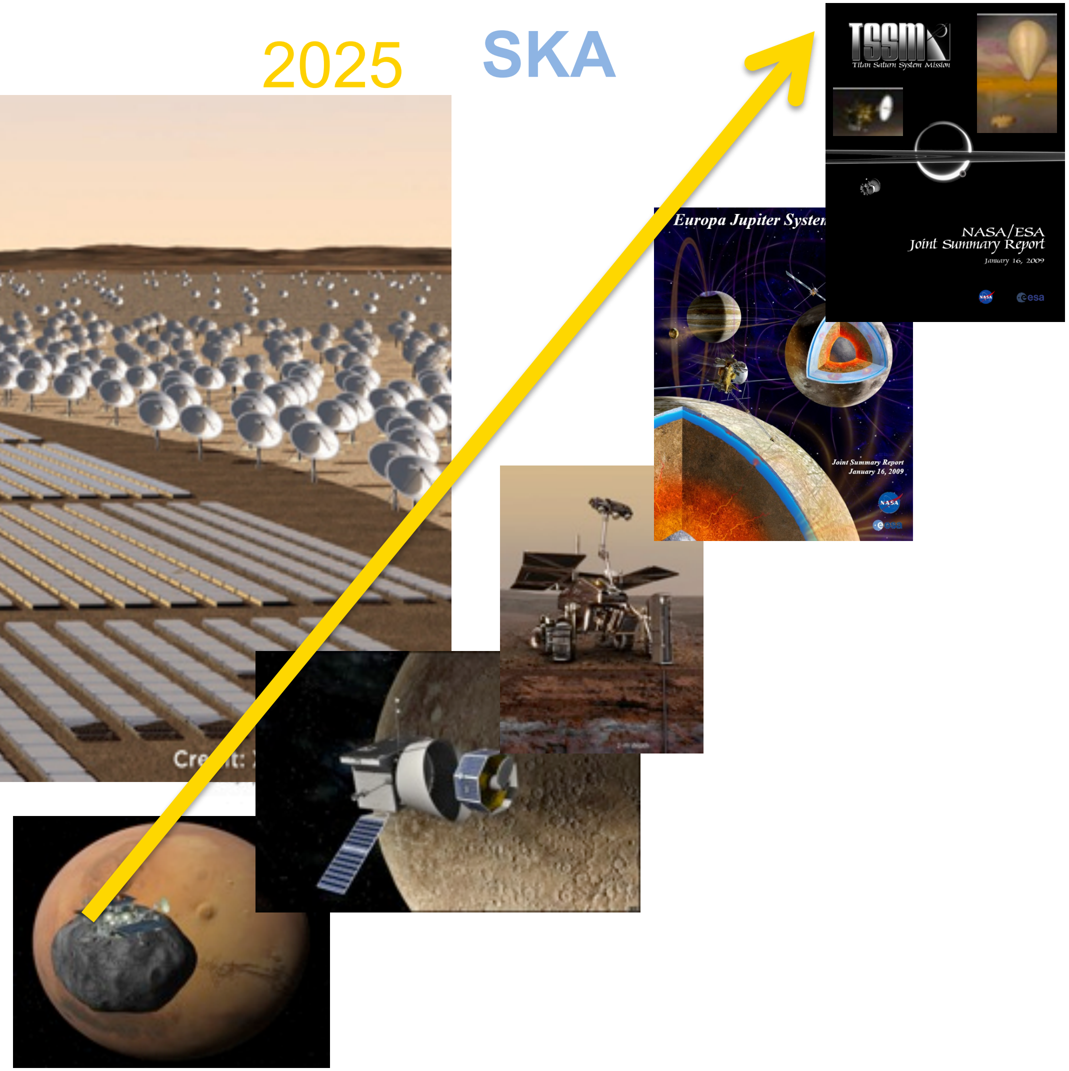
Future planetary missions

VLBI Network of radio telescopes

2025

SKA





2011

VLBI

General concepts

Allows t

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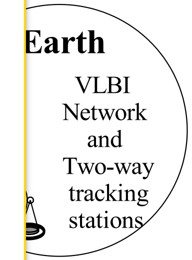
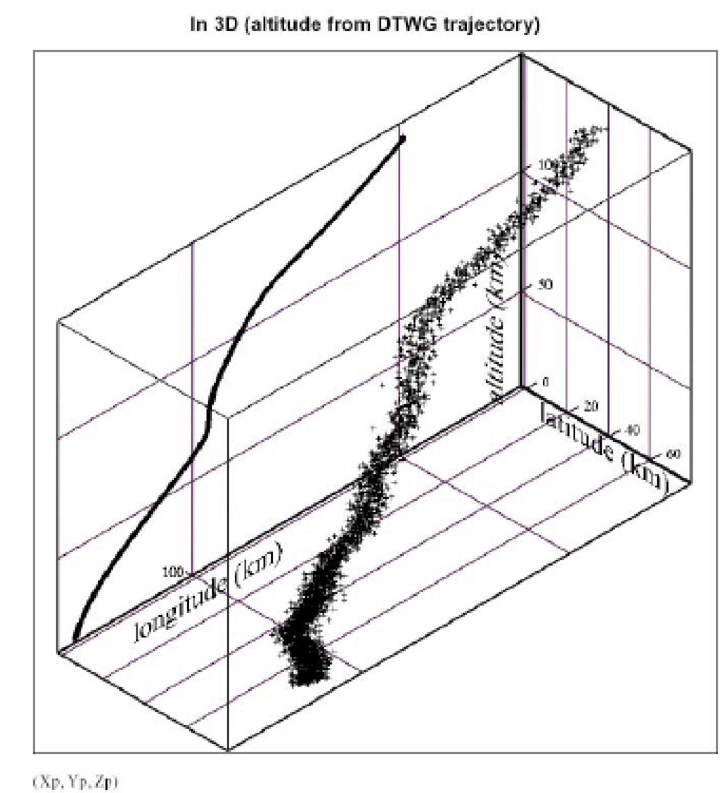
from distant





Tracking of the descent and landing of Huygens with VLBI radio telescopes (L. Gurvits and S. Pogrebenko 2004).

strong

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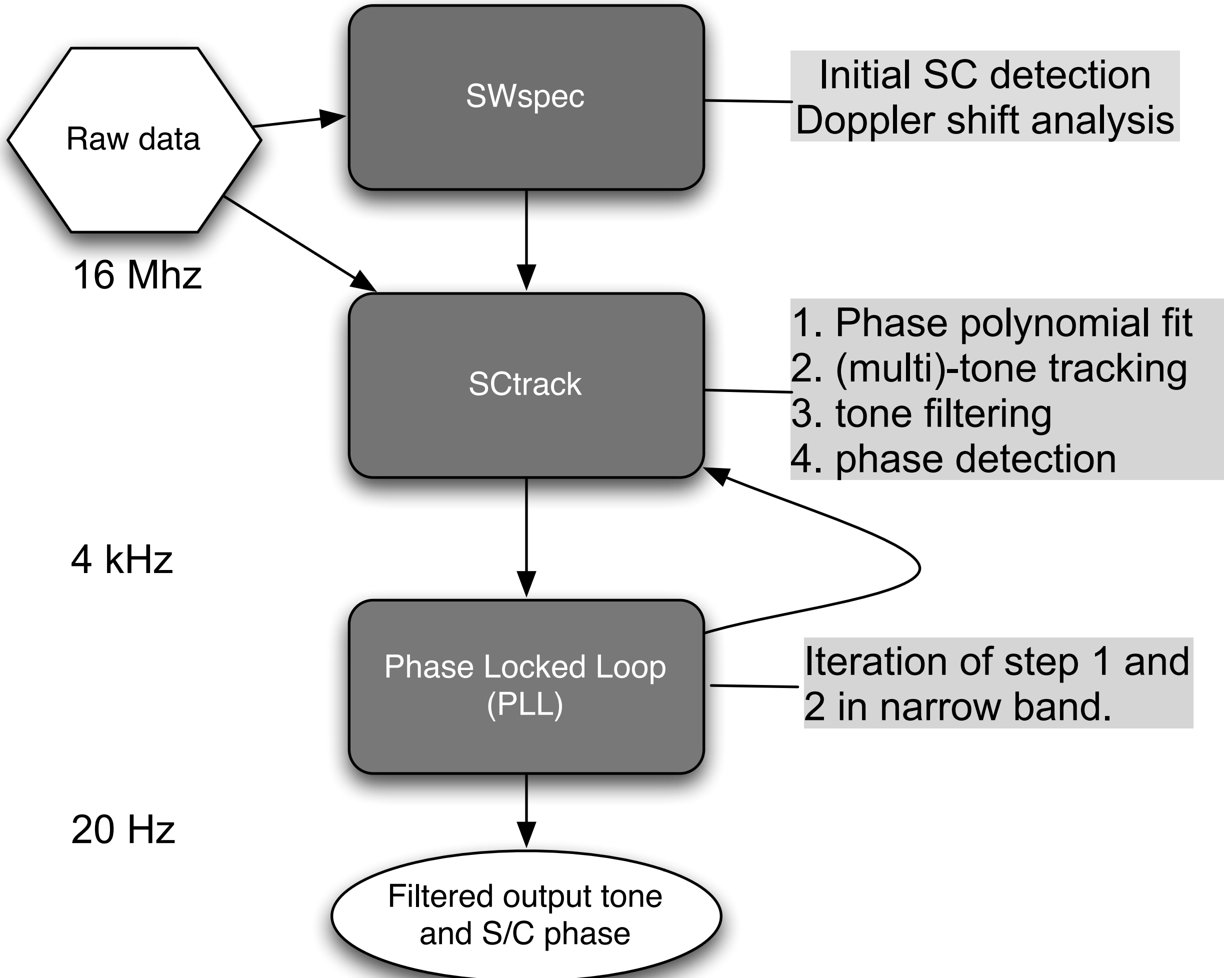
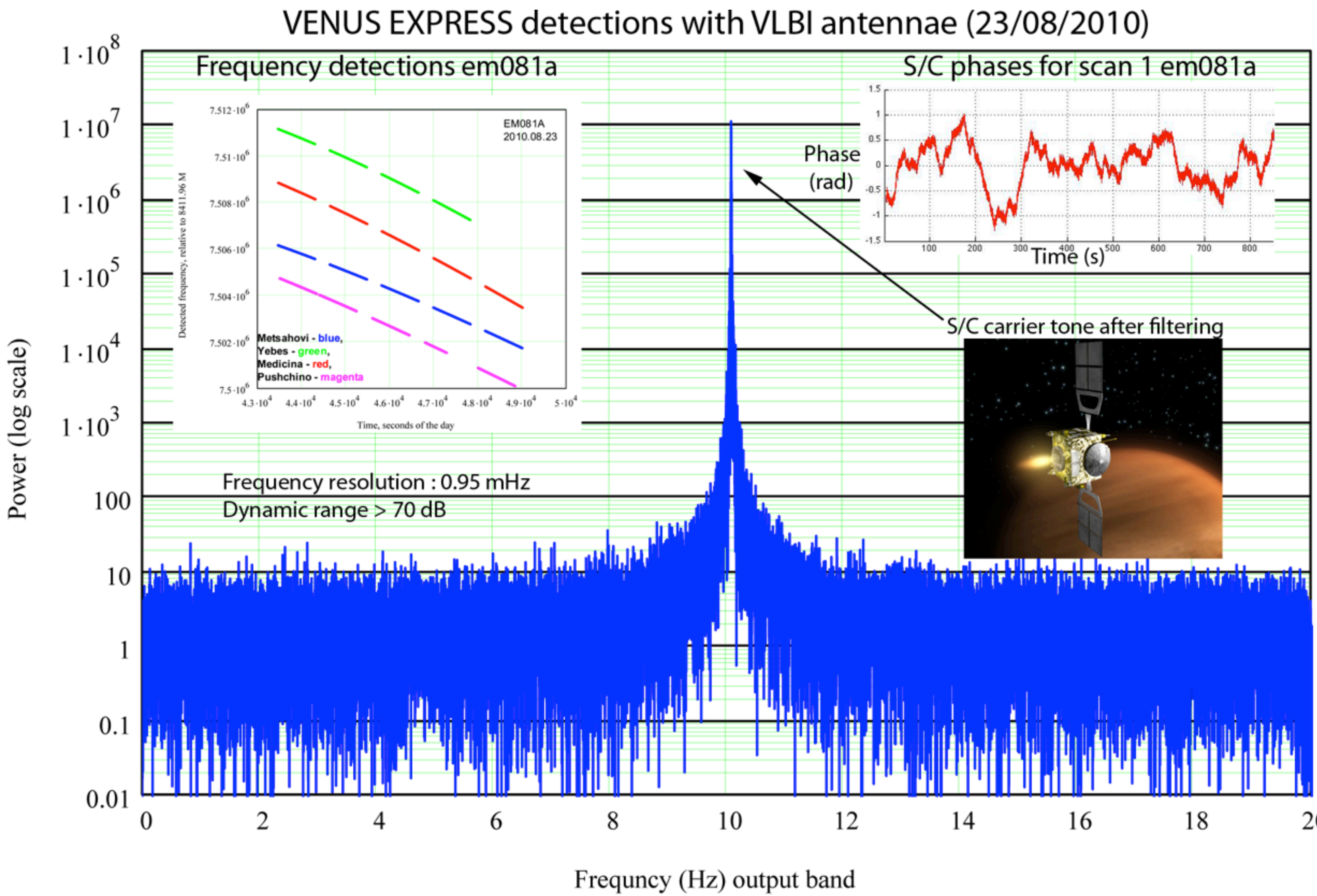
Tracking software



Spacecraft detection

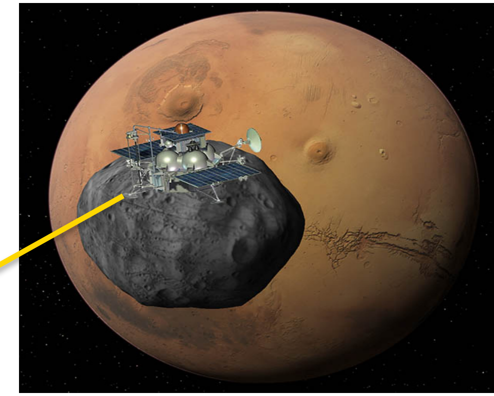


Phobos-Soil vs. Venus Express

P = 1W (0 dBi) Phobos Soil
+ ~10 MHz tones from the carrier.

Data TX at X-band

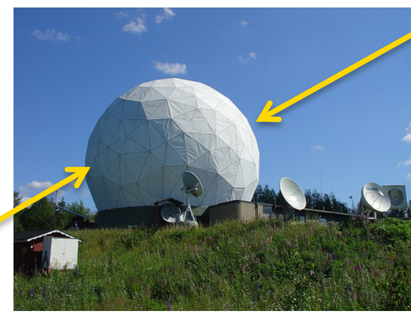
SNR = 4.12 @1Hz & 1AU



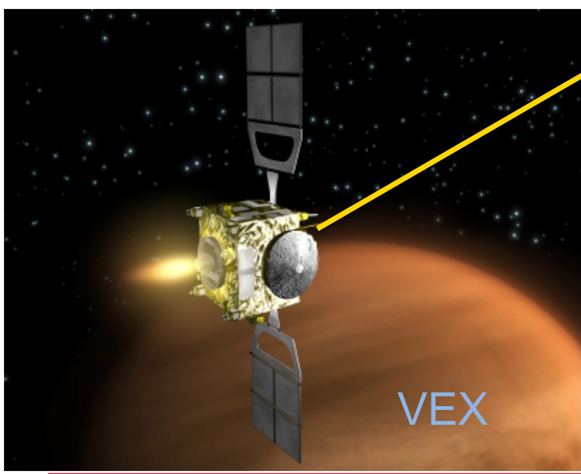
Phobos Soil

Typical detections of VEX spacecraft for a 32-m dish:

SNR = 9000 @ 5Hz & 1AU



Metsähovi, Finland

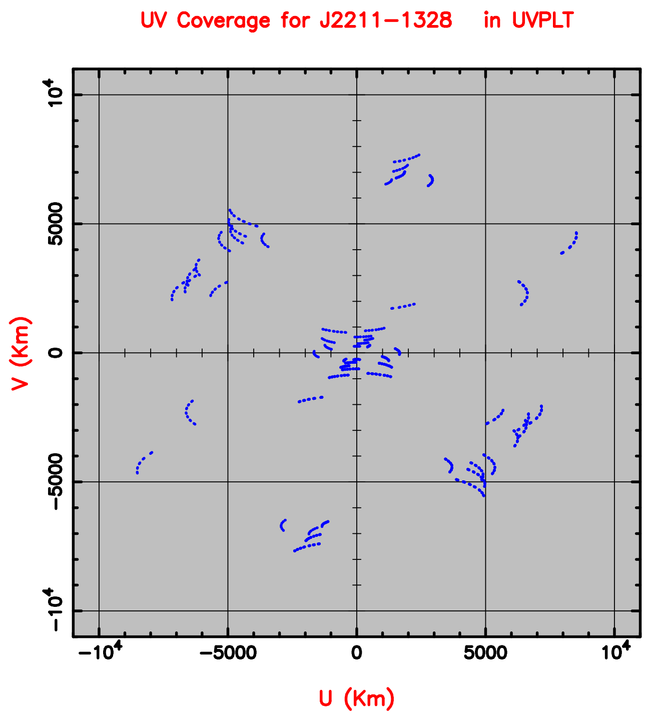


7th sub-carrier of VEX ~ PhG Power -195 dBW

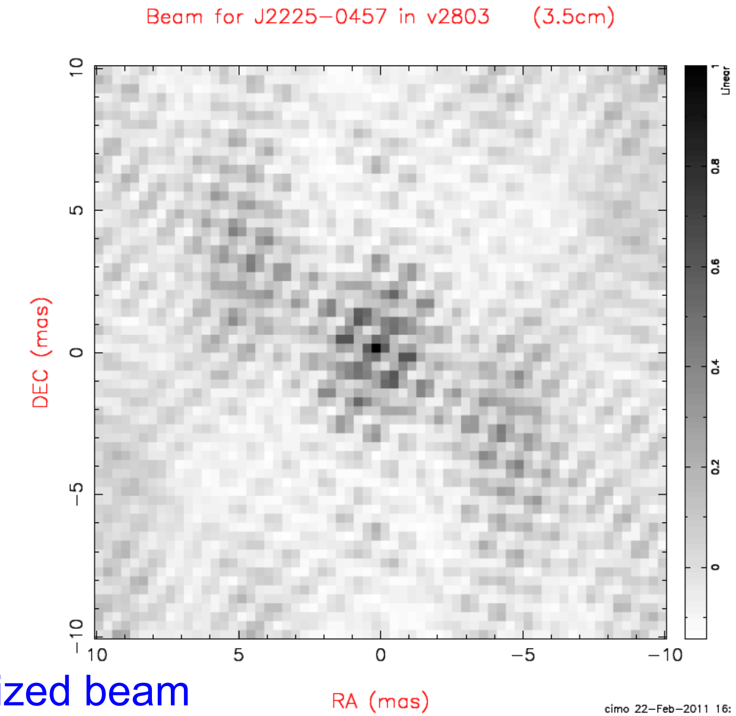
Detection at 3 s. and 0.15 Hz tracking bandwidth -> phase noise 0.4 rad and Doppler noise level at 11 mHz.

Tracking results

- The em081c VLBI spacecraft session was observed on the 28th March 2011. We used 10 radio telescopes, the biggest telescope in the network was 40m (Spain). The largest baseline were set by the baselines Mh-Hh / St-Zn.
- We used two different calibrator sources, and alternate observing VEX and quasars with 4 minutes nodding cycle. 80 scans in total and more than 2.5 TB of data in two hours.



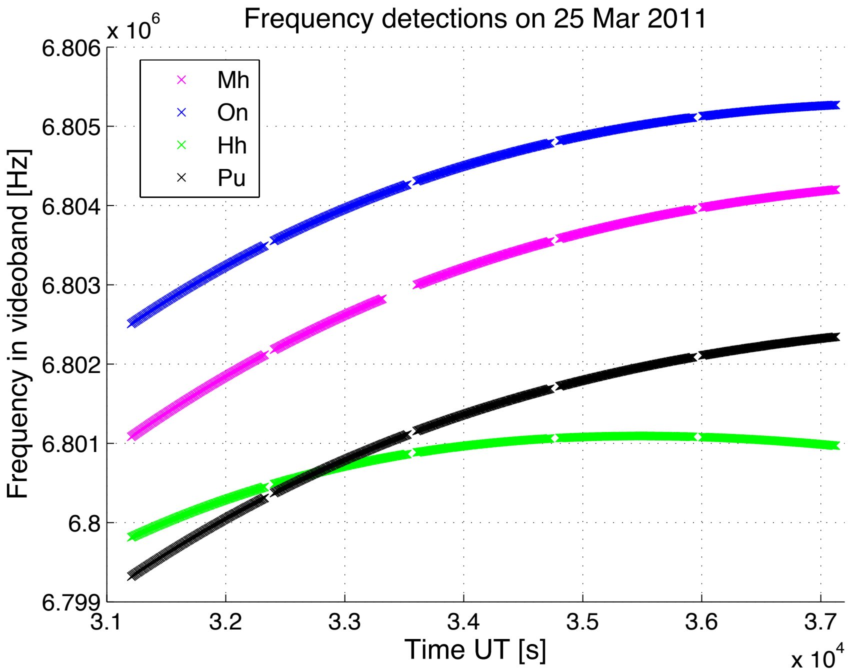
UV coverage

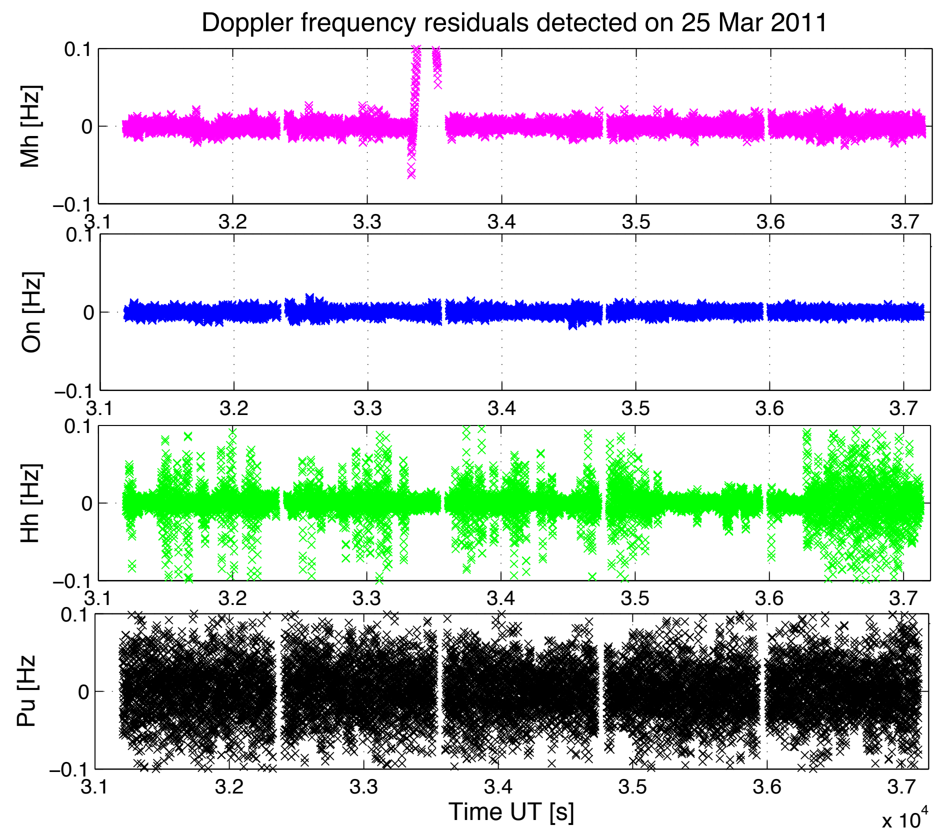


Synthesized beam

Doppler detections per station

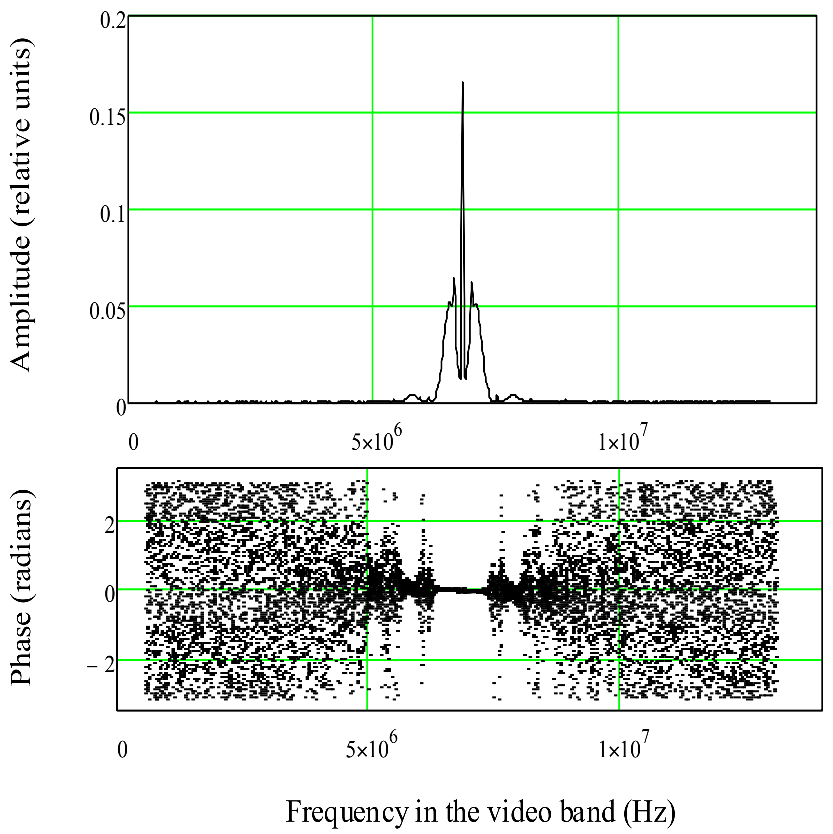
The v1100325 session was observed three days before em081c, including 4 radio telescopes.

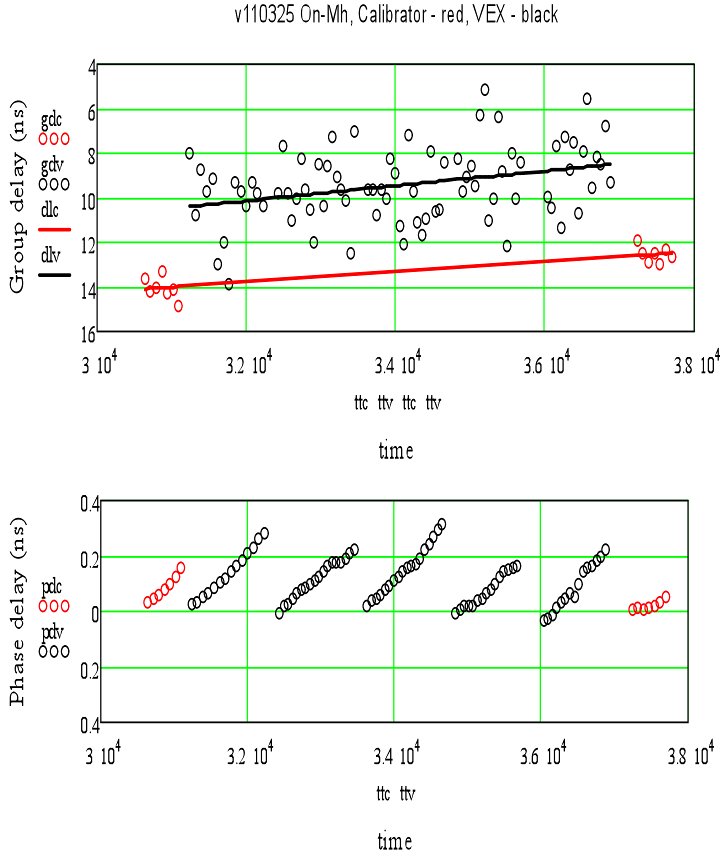




Broad-band correlation

- Single baseline correlation results: Onsala – Metsähovi.
- Group and phase delays for the VEX signal and the reference source.

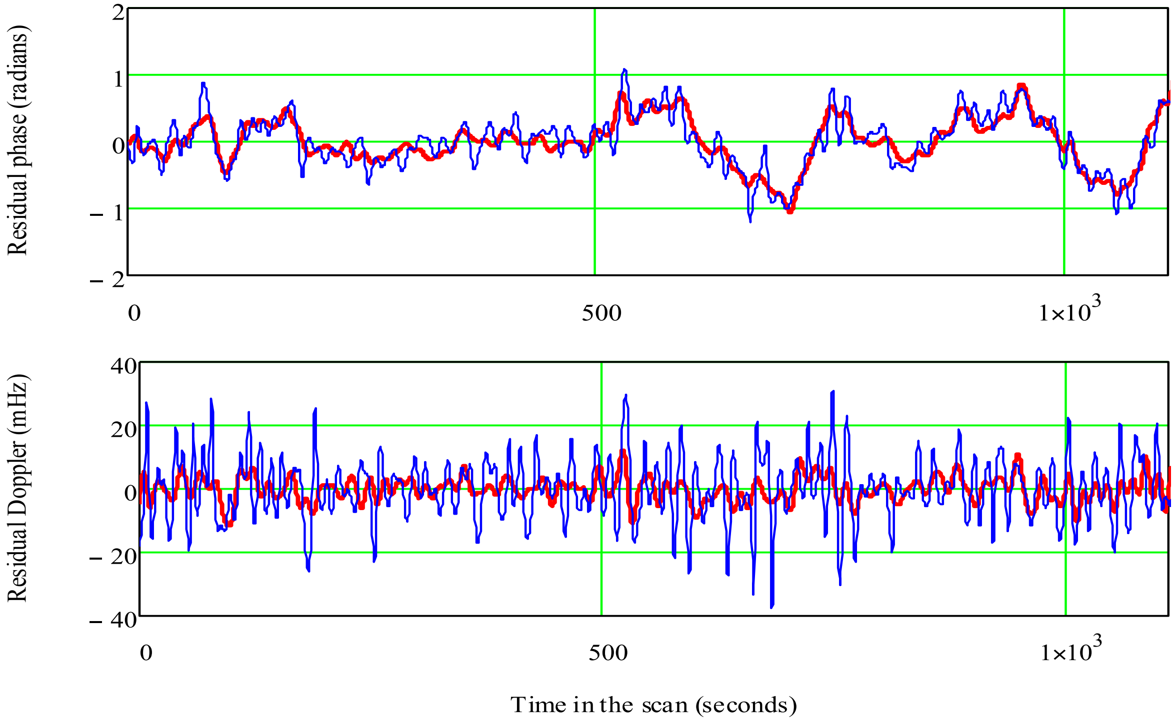




Doppler and phase residuals for PhG?

Detection of the 7th VEX sub-carrier tone. . In the terms of power, this tone can be used to mimic the Phobos Soil carrier signal.

The accuracy of the detection is dominated by IP scintillations rather than system noise.

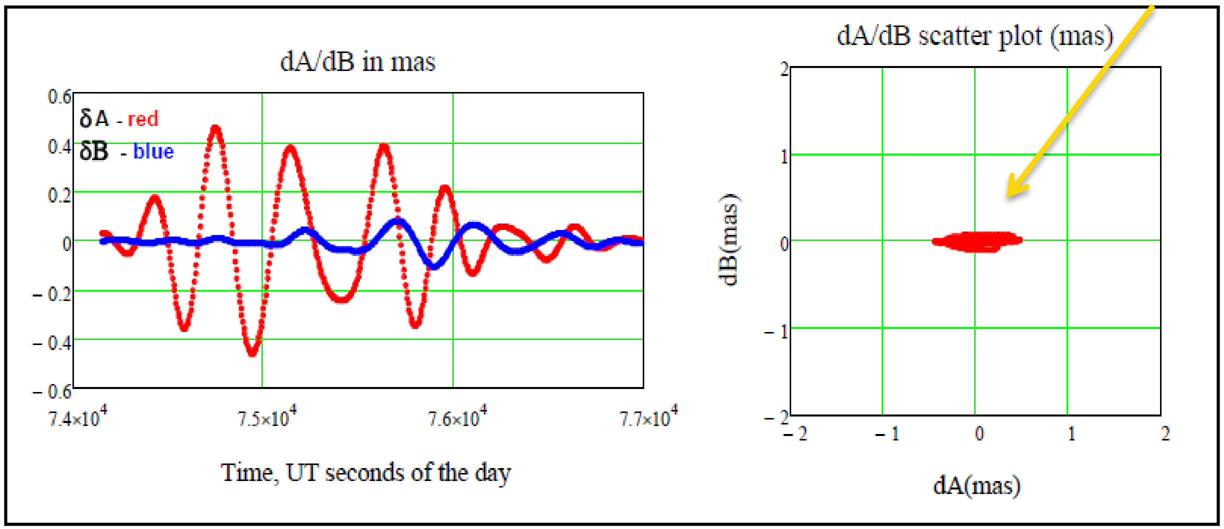


VEX carrier
P = -165 dBW
7th tone
P = -195 dBW

Spacecraft state vectors estimates

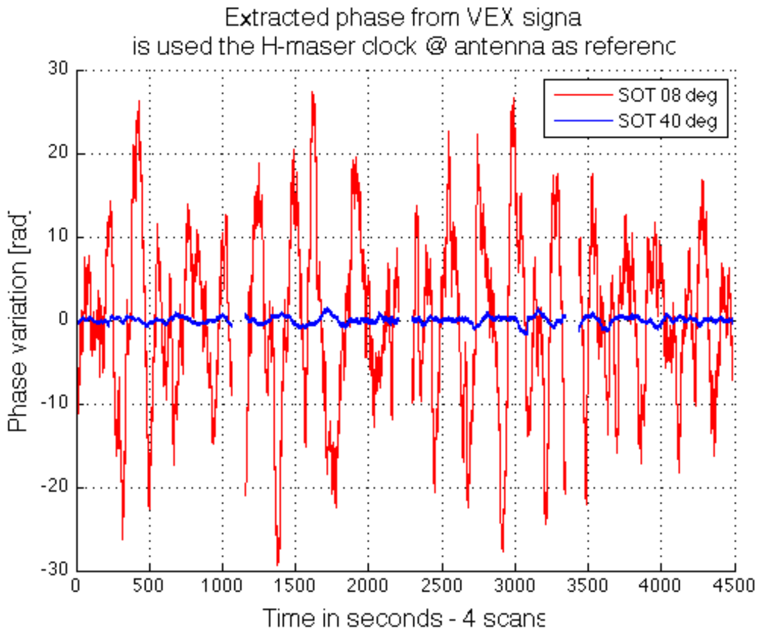
- Residual delays from the calibrator
- S/C residual phases
- Lateral coordinates dRa/dDec
- Lateral coordinates dA/dB

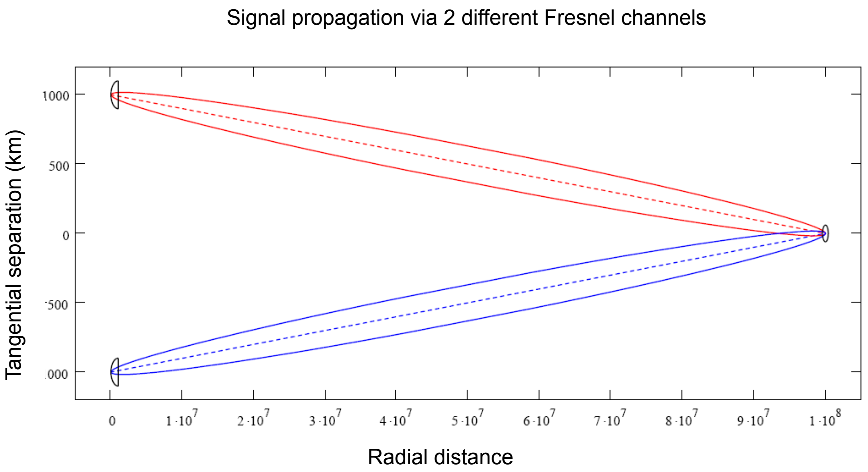
deviation 0.19 - 0.035 mas.
170 - 30 m



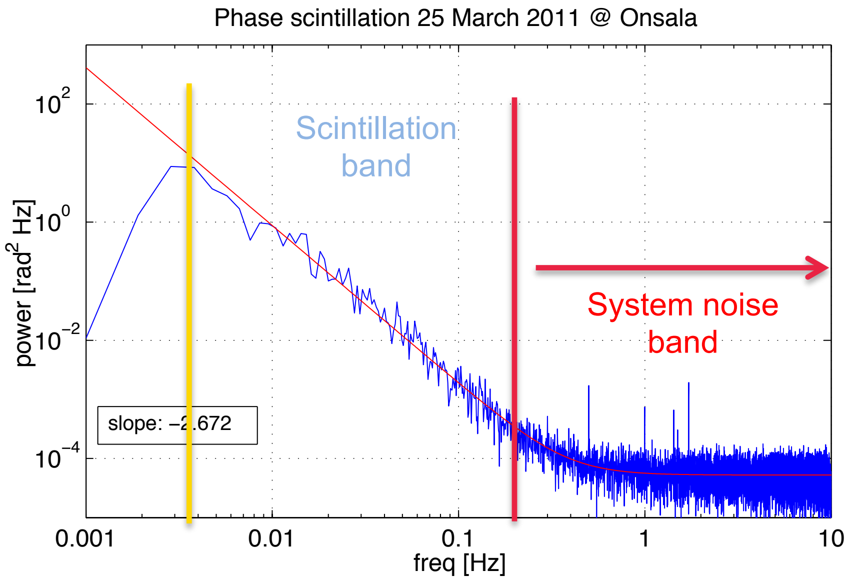
Interplanetary Plasma scintillations (I)

- Study of the phase fluctuations can be used to characterise the IP scintillations.
- 2 years – more than 60 observations
- Phase scintillation index direct relation with the solar elongation, distance to the target, solar activity and radio telescope

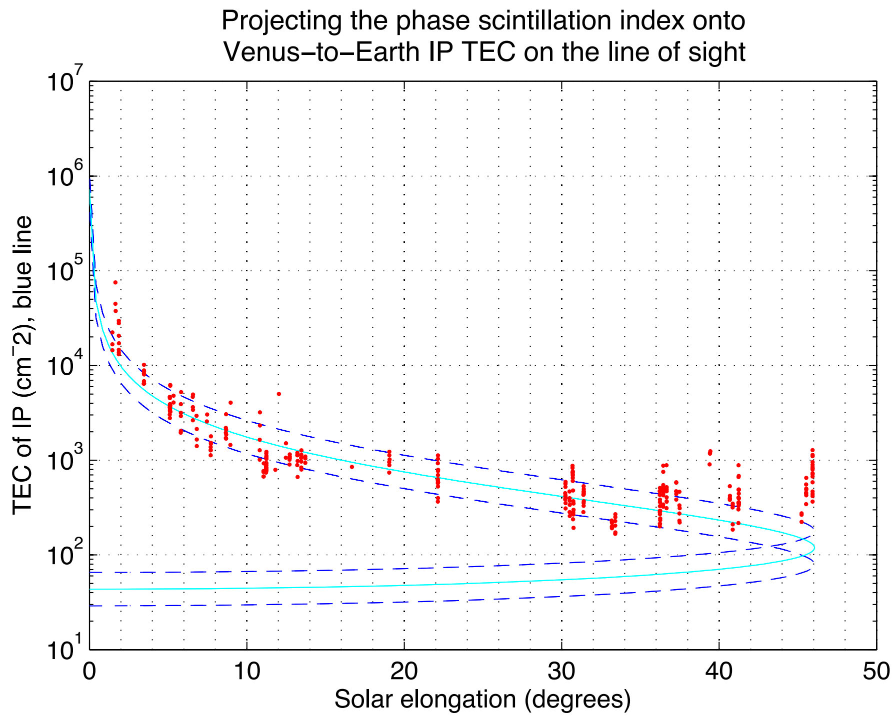




Interplanetary Plasma scintillations (II)



Measured TEC and projection of the phase scintillation index.



Phase scintillation spectra observed in our detections are well represented by a near-Kolmogorov spectrum.

Final Thoughts

VLBI antennas are capable of detecting really weak signal.

Further work is needed to optimize and improve accuracy and rapidness of the results.

Software is adjustable to any requirements and scenarios for future space mission.

Valuable scientific results will be obtained from the radio science experiments.